CALIFORNIA SNOW SURVEYS [1]

By HARLOWE M. STAFFORD, Hydraulic Engineer, Division of Water Rights, State Department of Public Works

It was only in the last day or so that I was advised that a statement was desired at this meeting from our State department concerning the proposed entry of the State into the work of the Sierra snow survey. For this reason and also because of the fact that the project is still in very preliminary stages, my remarks will be somewhat brief and sketchy. When the work is under way and opportunity is afforded for study and analysis, we shall be pleased to offer you something which I am sure will be much more profitable than my present statement.

The history of California snow surveys, so far as the State itself is concerned, goes back to about 1917, when Major Norboe, then chief assistant State engineer, arranged for an informal cooperation with Nevada for surveys at a few stations. This cooperative effort was continued until about 1923, when California withdrew because further funds for this work were not then available. During this period the cooperative snow surveys were conducted chiefly in the Yuba, Tahoe, Truckee, and Carson Basins, at summit stations of the American and Mokelumne, and, I believe, in the upper Walker Basins.

Major Norboe was in very close touch with Doctor Church, of Nevada, and the methods employed in the surveys were largely those devloped by Doctor Church in the Nevada work.

I believe Doctor Church has appeared before this society many times and that you are probably thoroughly familiar with his work and international reputation in snow surveying. This brief reference should therefore be sufficient.

About two years ago there appeared to be a growing demand that California should again reenter the snow-survey work, and the California Development Association, through its California Economic Research Council, adopted the furtherance of this idea as one of its projects. Request was made of Mr. Conkling, chief of the State division of water rights and a member of the research council, that his department conduct an investigation to determine the extent of present snow-survey work on the part of power companies, irrigation districts, and others and to sound out the general desirability and demand for any extensive work of this nature by the State. Questionnaires were sent to a number of these agencies, and the speaker made contact with many and obtained reports of the data now being obtained, their methods, and the degree to which dependable forecasts were possible from the results of the surveys. A conference was also held at Reno with Doctor Church and Professor Boardman, chairman of Nevada's cooperative snow survey committee, and the possibilities of the California work were discussed.

As a result of its investigation the division of water rights reported on January 14, 1929, to a special conference of the research council members and representatives of those public and private agencies directly interested, that nearly every agency was strongly in favor of the States undertaking this work and that the results that had so far been obtained by Nevada and the agencies in California would appear to justify such a step. Accordingly, action was taken to forward the proper legislation at the recent session of the legislature. I wish to read a portion of the letter sent by this conference to Mr. A. R. Heron, director State department of finance, and to Mr. B. B. Meek, director State department public works, as this sets forth clearly and briefly the purposes of this work and what it is hoped may be attained:

SPECIAL CONFERENCE ON SNOW-SURVEY PROJECT

SACRAMENTO, *January 14, 1929.*

Chairman C. L. Hill, of the natural resources committee, California Economic Research Council, called a special conference of the representatives of those public and private agencies most directly interested in the possible results of snow-survey investigations, in Sacramento on January 14. The object of the conference was to consider the various needs for such work, its importance and possibilities, and to present a unified statement or recommendation to the State departments involved or to the legislature.

Those in attendance included C. L. Hill, United States Forest Service (chairman): H. F. Ormsby, secretary California Economic Research Council; E. H. Bowie, United States Weather Bureau; William Durbrow, president Irrigation Districts Association of California; F. R. George, Pacific Gas & Electric Co.; Charles Mardel, Great Western Power Co.; C. A. Logan, State division of mines and mining, Harold Conkling, chief; and Harlowe Stafford, State division of water rights.

Results of the conference are summarized in the following letter and recommendations:

Copy of letter sent to Mr. B. B. Meek, director department of public works, and to Mr. A. R. Heron, director State department of finance.

"Some time ago the California Economic Research Council, pursuing its objective of improving our basic sources of useful economic information, agreed in a general statement, acted upon by its entire membership, that comprehensive state-wide records of snowfall and snow pack would be a most valuable and necessary extension, due to the increasing importance of forecasting the annual water crop from our high mountain watersheds.

"Accordingly, this council committee on natural resources was authorized to investigate the various practical needs, the present facilities available, and the possible direction and results of coordination and extension of this work. At the request of this committee your State division of water rights has collected information along these lines, summarized in a mimeographed report inclosed. (Copies of this report can be obtained from the State division of water rights.)

"On January 14 the chairman of this committee called a conference in Sacramento to review the situation and to recommend such action as would seem desirable by a representing group of those interests most directly affected. This included representatives of the two major power companies operating in the Sacramento and San Joaquin Valleys, the irrigation districts of the State, the United States Weather Bureau, the United States Forest Service, the State division of mines and mining, the State division of water rights, and the California Development Association.

"The information developed through this conference and previous investigation was, briefly, that the snow-survey work now done by the power utilities, irrigation districts, and other private interests, such as Professor Church, of the University of Nevada, has proven that reliable forecasts of run-off are possible on local watersheds. It is most desirable that these scattered private efforts be coordinated under State supervision, and they have expressed their willingness to cooperate. That in addition to standardizing and centralizing the information now privately collected, the State should extend the work to fill the gaps and obtain comprehensive annual records for at least the entire Sierra Nevada watershed.

"The benefits to be derived from an adequate system of state-wide snow surveys and water-run-off predictions are not confined to the immediate practical or local uses by power companies, irrigation districts, and municipal water companies in the administration of their projects. The broader necessity is for such information to guide the use of water from year to year over large areas, such as the entire length of the Sacramento River, where for example, an increased acreage of rice by upper water users means a diminished flow in the delta region and salt-water incursion if the summer flow is not ample. The same condition and necessity applies on the San Joaquin River, Kings River, etc. The power utilities and power projects in connection with irrigation also can use the information in a broader way to forecast the load demand for pumping in the areas they serve.

[1] Presented at the meeting of American Meteorological Society, Berkeley, Calif., June 21, 1929.

"In view of these facts, the conference assembled decided that immediate action was necessary, in order to start such work, and adopted the following recommendations, which are presented for approval by you; and by other agencies interested.

"'1. *Resolved*, That state-wide snow surveys for the purpose of predicting water run-off are desirable, and that the State should undertake the standardization and correlation of private work now under way.

"'2. *Resolved further*, That the State should extend these snow surveys to include an adequate record for the entire Sierra Nevada watershed, presumably through its present division of water resources.

"'3. *Resolved further*, That legislative authorization and appropriation of funds to permit the initiation of this work during the forthcoming biennium should be sought immediately.'

" In the interest of time, this conference group has had drafted a bill carrying a biennial appropriation of $40,000 for introduction before the close of the present session of the legislature. The estimate of cost was submitted at our request by the division of water rights.

"Realizing your knowledge of the water situation, we are presenting this matter for your consideration without the more detailed information which could be given, and would ask in behalf of the conference group your indorsement of the proposed legislation.

"Sincerely yours,

"(Signed) C. L. HILL,
"*Chairman Natural Resources Committee.*"

Copy of suggested legislation:

STATE-WIDE SNOW SURVEYS

"An act to provide for the making of snow surveys and the gathering and coorelation of information pertinent to an annual forecast of seasonal water crop and making an appropriation therefor.

"The people of the State of California do enact as follows:

"SECTION 1. The division of water rights of the department of public works is hereby authorized and instructed to make snow surveys and to gather and correlate information for the purpose of acquiring data necessary to an annual forecast of seasonal water crop and to do all or any of such work either independently or in cooperation with one or more persons, firms, associations, corporations, or other agencies, including county, State, and Federal agencies.

"SEC. 2. For the purpose of carrying out the provisions of this act the sum of forty thousand dollars ($40,000) is hereby appropriated out of any money in the State treasury not otherwise appropriated, and the State controller is hereby directed to draw warrants upon such sum from time to time upon requisitions of the division of water rights as approved by the department of finance, and the State treasurer is hereby directed to pay such warrants."

(Assembly bill 403, introduced by Assemblyman Crittenden on January 16.)

An appropriation of $30,000 for the California snow surveys was passed by the legislature and just signed by the governor within the last few days.

As to the program for the work, the letter which I have read outlines in general the scope. It entails a coordination, standardization, and centralization of the work and data now conducted and secured through scattered private effort, as well as considerable extension, to make the survey as complete as possible with the funds available.

In a voluminous report submitted in 1923 to the California State engineer by Doctor Church, an outline was given for a comprehensive snow survey of the Sierras, and, as far as present plans have been formulated, this outline will be used as a guide in developing the work. Also the survey methods developed by Doctor Church will be largely used. As I have said, I believe you are familiar with these methods. In briefest terms, the procedure comprehends the determination of the water content of the snow cover over properly selected snow courses in each basin or region by means of suitable sampling apparatus and, from the data obtained, the determination of the percentage relationship of the seasonal snow cover of that basin to its normal, under the assumption that such percentage is indicative of the coming seasonal run-off in the streams below.

Under the plan suggested the Sierras are divided into the northern, the central, and the southern quadrangles, and in each quadrangle the survey would cover the various basins by means of sufficient courses at crest, eastern and western outposts. In the northern quadrangle there would be the Upper Klamath, the Upper Sacramento, the McCloud, and the Pit Basins; in the central, the Feather-Honey Lake, Yuba-Truckee, American-Tahoe, Mokelumne-Carson, and Stanislaus-Tuolumne-Walker; in the southern, the Merced-Mono, San Joaquin-Upper Owens, Kings-Kern-Lower Owens, and Kaweah-Tule.

The investigation by the division showed that more or less extensive surveys are now being made annually in the South Yuba and Upper Mokelumne Basins by the Pacific Gas & Electric Co. at some 11 stations, totaling 17 snow courses; in the North and West Kings River and North San Joaquin Basins by the San Joaquin Light & Power Corporation at some 40 stations and courses; in the Upper San Joaquin Basin by the Southern California Edison Co.; from Cottonwood Basin, at the lower end of Owens Valley, to the Mono Summit above Long Valley by the Los Angeles Bureau of Water Supply; in the Bishop, Rush, Leevining, and Mill Creek Basins, in Mono and Inyo Counties, by the Southern Sierras Power Co.; in the Lake Almanor and Butt Valley watersheds by the Great Western Power Co.; in the North and Middle Yuba Basins by the Nevada Irrigation District; in the Merced Basin by the Merced Irrigation District; and in the various basins draining to Nevada which come, of course, under the State of Nevada Cooperative Snow Surveys.

In nearly every case the Church methods or some modification thereof are being employed. In some cases the data have been analyzed to determine actual estimates of run-off which have proved notably accurate, and in others the data are merely tabulated for comparative purposes, but no definite forecasts of run-off made.

One of the chief functions of the State snow survey will be the correlation of these individual efforts, and in all cases a great willingness and earnest desire to cooperate with the State has been expressed.

In the extension of the work to fill in the gaps and supplement the present surveys the problems are not simple. Where the snow-cover run-off relation is confined to the upper basins and high altitudes, the physical difficulties are of course considerable, but those attendant upon the interpretation of data and analysis are comparatively slight. When we come to the lower elevations, however, and attempt to forecast run-off at foothill and valley points, we enter the zone of early melting snow, precipitation, as rainfall, etc., and the difficulties increase. In the Sacramento Basin, as an exmple, the stream flow is derived largely from storage in the lava beds derived mostly from rainfall, with some melting snow. It goes without saying that the snow survey must be definitely tied in with the many precipitation stations of the United States Weather Bureau at the lower elevations if proper forecasts for the lower points are to be made. In each quadrangle it will also probably be necessary to establish supplementary precipitation and temperature stations. In addition, at certain key stations it may be advisable to establish facilities for observation of more complete meteorological data, such as humidity, pressure, temperature, wind direction and velocity, etc. In the conduct of the snow surveys the plan would call for one complete survey at all courses about April 1 of each year for the preparation of the main forecast bulletin as of

about that date. At slected stations and courses, however, the survey may be conducted monthly or at frequent intervals to furnish the data for supplementary forecasts prior and subsequent to the main forecast.

The task is rather large and must be approached cautiously. The establishment of new courses will take some time. The selection must of course be made in the winter when the snow is there and when the suitable location of shelter huts, etc., can only be made. Little more than reconnaissance can therefore be expected in the coming winter for the new stations. The following summer the shelter huts can be built and stocked and the courses carefully marked in preparation for the actual surveys the following winter. In the meantime, however, there is much that can be done in the way of securing standardization and distribution of equipment, organization of personnel, preparation of standard forms, arrangements for cooperation with existing surveys and standardization of them as to methods, reports, equipment, etc.

This may serve to give you some idea of the project and what lies before us. As I stated in the beginning, when the results of two or more years are behind us we may be able to bring to you, should you desire it, something of greater interest to a scientific body of this nature than the mere prospectus of a project.

NOTES, ABSTRACTS, AND REVIEWS

Origin of nor'westers.—During spring and summer Bengal is occasionally visited by a type of severe thunderstorms locally known as the *Kal-Baisakhi*, or the "fateful thing" of the month of *Baisakh* (April 15–May 15). These storms usually approach a station from the northwest and burst suddenly with great fury. The path of a nor'wester may vary in width from a few hundred feet to a mile, and the distance overrun seldom exceeds 50 miles. These storms are more frequent in the late afternoon, although they are known to occur also at other times of the day. A nor'wester is always associated with a thundershower, and the precursory signs of its approach are the same as those which herald the coming of a violent thunderstorm.

During last summer one of us (G. Chatterji) led an expedition to south Bengal to study the upper air condi-

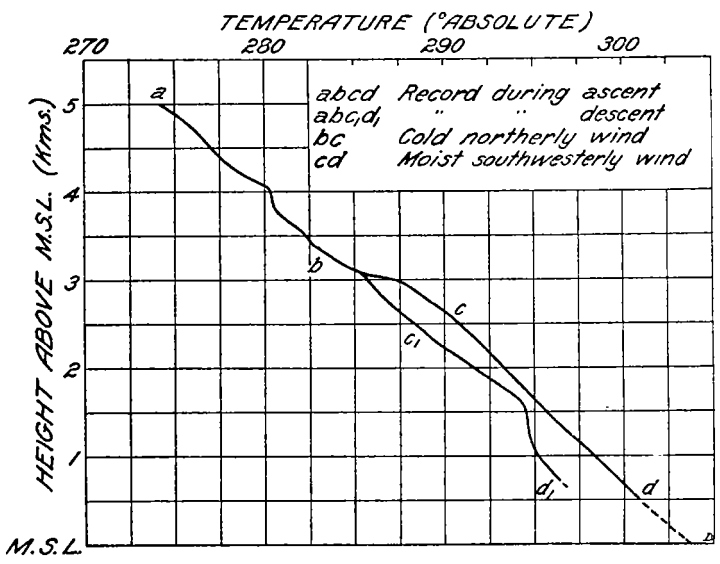

FIGURE 1.—Upper air soundings over Jhikargacha, Bengal, on May 17, 1929, at 17 hr. 35 m. I. S. T., just before a nor'wester

tions associated with nor'westers. On three occasions it was possible to collect some information from soundings by Dines and Chatterji meteorographs. A typical height-temperature graph obtained on one occasion just before the passage of a storm is reproduced in Figure 1. It appears that the nor'wester type of thunderstorms originates through the overrunning of a warm moist southerly or southwesterly wind by a westerly or northwesterly cold air with a high lapse rate. In the present case the cold air orveran the moist air at 2.7 km. and extended to 3.3 km. The air in this layer had a superadiabatic lapse rate of 12° C. per km. while the air underneath was almost saturated and had a lapse rate of 5° C. per km. On all the three occasions the "overrunning" took place in the southeastern quadrant of a low-pressure area which developed a "wind-shift line" more or less defined.

Thus the general conditions under which nor'westers occur in Bengal appear to be exactly similar to those giving rise to "tornadic" thunderstorms in the Mississippi Valley of the United States of America (Humphreys, "Physics of the air," p. 344). Upper air soundings on nor'wester days show that there is a marked increase in the absolute humidity of the southerly current from the Bay of Bengal in the afternoon. This probably explains why the nor'wester type of thunderstorms is more frequent during the afternoon than at any other hour of the day.—*S. C. Roy and G. Chatterji.*

A 24-monthly period of rainfall fluctuation in Saragossa.—A statistical examination of the monthly rainfall at Saragossa has revealed a well-marked periodicity of rather more than 24 months.[1] Saragossa is to the south of the Pyrenees in the valley of the river Ebro in the center of the Province of Aragon. In this region the summer and winter rains are about equal, but on the average the spring fall exceeds that of the summer and the autumn that of the winter. In order to eliminate this seasonal variation the rainfall values for successive 12 months have been examined for the period 1910 to 1924. When these values are plotted the recurrence of maximum values and minimum values at intervals of 12 months is clearly demonstrated. The periodicity is given as rather more than 24 months, although less than 25 months. It is also noted that harmonic analysis has not revealed the existence of smaller components of this value.

It is interesting to recall that in the case of our own country, where longer records are available, it has been shown that the 2-year recurrence is really compounded of two periodicities of 1.7 and 2.1 years, both of which have persisted with very little change through two centuries at least.—*J. Glasspoole.*

On the cause of banner clouds.—Dr. Roderick Peattie has recently described numerous observations of his on certain banner clouds in southern France.[2] He found no support for the explanation of banner clouds as a result either of reduced pressure in the lee of a peak which by expansional chilling of the passing air produces cloud, or from chilling of the wind by the peak. What he saw was the formation of convectional clouds in ascending currents of valleys in the lee of the wind at the level of the peak. These ascending currents, more humid than the

[1] *Sobre un Periodo de unos veinticuatro meses para la fluctuatión de la precipitatión en Zaragoza*, by José Domingo y Quílez; Madrid, An. Soc. Española Meteor., 2, 1928, pp. 9–15.

[2] R. Peattie, Nuages en bannière—Petite etude des vents et des nuages de montagne. Revue de Geographie Alpine, Vol. XVII, 1929, p. 329–335, 3 figs.